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Computed Tomography / Tomodensitométrie

Dose-Length Product to Effective Dose Conversion Factors for Common Computed Tomography Examinations Based on Canadian Clinical Experience

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Modern computed tomography (CT) scanners report the dose-length product (DLP). Although the DLP is related to patient dose and risk, it is unique to CT and is not useful for comparisons with other modalities. The International Commission on Radiation Projection (ICRP) uses the concept of effective dose (E), in units of J/kg or sievert (Sv), to quantify risk [1,2]. The E is a weighted sum of the organ doses, in which the weights represent the relative sensitivity of organs to radiation damage and their contribution to overall determinant from stochastic effects (cancer). Generally, the risk of a fatal cancer for adults is estimated at 5%/Sv [1] and is higher for children. DLP-to-E conversion factors have been derived and are useful in quickly estimating patient risk from the DLP values reported by CT systems [3,4]. Recently, the ICRP updated the tissue-weighting factors [1], which necessitates that the DLP-to-E conversion factors be updated as well. Several articles have proposed new DLP-to-E conversion factors for the case of a single CT scanner model [5,6]. Recently, Huda et al [7] published updated average conversion factors based on ICRP 103 but did not provide scanner-specific results.

In this technical note, we present DLP-to-E conversion factors for 7 common CT examinations (brain, sinuses, lumbar spine, chest, abdomen-pelvis, cardiac angiography, and chest-abdomen-pelvis) and for 7 scanner models in use in Manitoba and other parts of Canada. We also present average conversion factors that can be applied, irrespective of scanner model. This work was carried out to facilitate

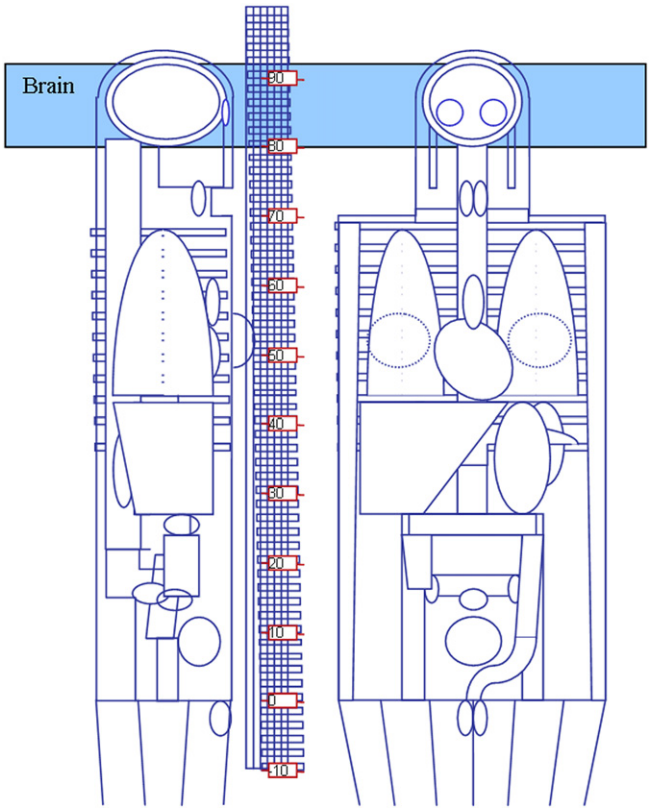

Figure 1. ImPACT (Imaging Performance Assessment of Computed Tomography Scanners) CT Patient Dosimetry Calculator numerical phantom, showing the scan range for the brain, starting at 80 cm and ending at 93 cm. This figure is available in colour online at http://carjonline.org/.

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Table 1
Scan start and end locations used in the ImPACT CT calculator for the clinical examinations considered in this study (start-end cm)

Brain	Sinuses	LSP	Chest	ABD/P	Angio	CAP
80-93	80-89.5	4-39.5	43-70.5	0.5-44.5	43.5-57.5	0.5-70.5

ABD/P = abdomen-pelvis CT; Angio = cardiac angiography; CAP = chest abdomen-pelvis CT; CT = computed tomography; ImPACT = Imaging Performance Assessment of Computed Tomography Scanners; LSP = lumbar spine CT.

calculating E from data obtained as a part of a provincial dose survey that has not yet been published.

Materials and Methods

We determined DLP-to-E conversion factors for adult patients by using the ImPACT (Imaging Performance Assessment of Computed Tomography Scanners) CT Patient Dosimetry Calculator (version 1.0.2) [8]. The ImPACT CT Patient Dosimetry Calculator is implemented as an Excel spreadsheet (Microsoft Corp., Redmon, WA) and is based on Monte Carlo dose data described in the National Radiological Protection Board's report SR250 [9]. The user inputs the CT scanning parameter and the start and end locations of the CT scan, and the ImPACT spreadsheet calculates the CT dose index (CTDI), DLP, and E for a standard hermaphrodite phantom.

The second author (I.D.C.K.) identified the start and end locations of each examination on the ImPACT spreadsheet patient figure, based on direct clinical experience with CT images from all CT scanners in Manitoba. The start and end locations of brain scans on the ImPACT spreadsheet patient figure are illustrated in Figure 1. The start and end points for all the examinations considered are listed in Table 1.

The scanner models included in this study are listed in Table 2. In the ImPACT dose spreadsheet, we set the kVp to 120 and the collimation field to the maximum beam width available. We used a pitch value of 1, a tube current of 100 mA, and a scan time of 1 second. We assumed a CTDI phantom 16 cm in diameter for the head region and a CTDI phantom 32 cm in diameter for all other regions. The ImPACT spreadsheet computed the E and the DLP, from which their conversion factor could be determined. We calculated DLP-to-E conversion factors for each scanner model and averaged them over all scanner models. We also determined their standard deviations and the maximum deviation from the mean.

Table 2
Scanner models in use in Manitoba for which DLP-to-E conversion factors were determined

Scanner model	No. detector rows	Maximum beam width (mm)
GE LightSpeed VCT[a]	64	40
GE LightSpeed 16[a]	16	20
Siemens Definition AS[b]	64	19.2
GE HiSpeed Nx/I Pro[a]	2	20
GE HiSpeed Qx/i[a]	4	20
Toshiba Aquilion[c]	16	32
Toshiba Asteion[c]	4	32

DLP = dose-length product; E = effective dose.
[a] From GE Healthcare, Waukesha, WI.
[b] From Siemens Healthcare, Forchheim, Germany.
[c] FromToshiba Medical Systems, Otawara, Japan.

Results and Discussion

The results for all scanners and their averages are summarized in Table 3. To facilitate comparisons, we also list the conversion factors used in the European CT quality-control standards [4] (based on ICRP 60) and those recently reported by Huda et al [7] (based on ICRP 103). Maximum deviation between scanner-specific conversion factors, and their averages were in the range of 10%-15%. Except for the

Table 3
DLP-to-E conversion factors (μSv/mGy·cm) for all scanners and clinical protocols considered in this study

	Brain	Sinuses	LSP	Chest	ABD/P	Angio	CAP
GE LightSpeed VCT[a]	2.8	3.1	17.4	16.7	16.5	27.1	18.0
GE LightSpeed 16[a]	2.6	2.8	19.5	19.0	16.1	26.6	17.3
Siemens Definition AS[b]	2.7	3.0	20.3	20.1	16.1	28.0	17.6
GE HiSpeed Nx/I Pro[a]	2.6	2.8	22.8	21.8	18.1	30.0	19.5
GE HiSpeed Qx/i[a]	2.6	2.8	20.0	19.4	16.1	27.0	17.3
Toshiba Aquilion[c]	2.3	2.5	20.5	19.8	16.7	27.5	17.9
Toshiba Asteion[c]	2.6	2.8	17.9	19.2	14.3	27.6	16.6
Average (SD)	2.6 ± 0.15	2.8 ± 0.19	19.8 ± 1.78	19.4 ± 1.51	16.3 ± 1.14	27.6 ± 1.01	17.8 ± 0.89
Maximum deviation from the average, %	11	11	15	14	12	7	10
European factors (ICRP 60)[d]	2.3			17.0	15.0-19.0		
Factors of Huda et al (ICRP 103)[e]	2.4			20.4	17.1		18.6

ABD/P = abdomen-pelvis computed tomography; Angio = cardiac angiography; CAP = chest-abdomen-pelvis computed tomography; DLP = dose-length product; E = effective dose; ICRP = International Commission on Radiological Protection; LSP = lumbar spine computed tomography.
[a] From GE Healthcare, Waukesha, WI.
[b] From Siemens Healthcare, Forchheim, Germany.
[c] From Toshiba Medical Systems, Otawara, Japan.
[d] From Ref. 4.
[e] From Ref. 5.

case of the abdomen-pelvis, the conversion factors we computed are higher than those based on ICRP 60.

The user has the choice between the scanner-specific conversion factor or can use average conversion factors. This range of variation of scanner-specific factors relative to their averages is larger than that reported by others [3]. Our study spans several models of scanners with detector rows that range from 2-64. The study described in the European guidelines on quality criteria for computed tomography [4], for example, reports on variations among 4 models of 16-slice scanners. Given the uncertainties inherent in the calculation of E [10], using average conversion factors is quite defensible.

The conversion factors proposed in this note are based on a single-tube potential of 120 kVp. Results of previous work indicate that conversion factors do not vary significantly with energy [5,6]. In addition, the choice of 120 kVp is ubiquitous in clinical practice in Manitoba. The ImPACT Dosimetry Calculator does not take into account automatic tube current modulation. With tube current modulation in place, it is estimated that E determined from DLP-to-E conversion factors is overestimated by 8%-11% [3,11]. The conversion factors provide clinicians and physicists with a quick and relatively accurate method to estimate E and patient risk. The E should be used with care. It does not represent the risk to any particular patient but is a useful concept for dose optimization, comparing technologies and modalities, and for population-based dose surveys and risk assessments [10].

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